Final Technical Report—USGS Cooperative Agreement for Montana Regional Seismograph Network Operations

Network name:	Montana Regional Seismograph Network
USGS Cooperative Agreement Number:	07HQAG0012
Principal Investigator:	Michael Stickney, Director Earthquake Studies Office Montana Bureau of Mines and Geology Montana Tech of the University of Montana 1300 W Park St Butte, MT 59701 (406) 496-4332 Voice (406) 496-4451 Fax mstickney@mtech.edu
Project web site:	http://mbmgquake.mtech.edu
Term covered by this report:	February 1, 2007 – January 31, 2010
Submital Date:	April 8, 2010

Abstract

The Montana Regional Seismic Network (MRSN) is operated by the Montana Bureau of Mines and Geology (MBMG) and is comprised of 35 stations that encompass approximately 80,000 km^2 of the northern Intermountain Seismic Belt in the Northern Rocky Mountains of western Montana. Network operations, data analysis, and information reporting are supported by the MBMG, USGS Cooperative Agreement 07HQAG0012, and the Confederated Salish and Kootenai Tribes. This cooperative agreement supports maintenance and repairs of seismograph stations and telemetry sites, and allows us to bring in a highly qualified seismograph technician for one week each year to diagnose and correct long-standing seismic telemetry problems. Over the past three years, we have analyzed and cataloged an annual average of approximately 1500 earthquakes using data from the MRSN.

Work Performed

A long-standing need was satisfied with the hiring of a full-time analyst/assistant in the Earthquake Studies Office. Debbie Smith was hired in January 2008 with approximately 50% of her salary supported by this cooperative agreement. With Debbie's assistance, we have caught up on the analysis of a 2-month backlog of un-reviewed earthquakes recorded by the Montana Regional Seismograph Network (MRSN) (Figure 1) that existed in 2008. Now we report reviewed locations for most earthquakes within 24–48 hours of their occurance. Also, the backlog of un-reviewed earthquakes for August 2005, the first full month following the July 26, 2005 Dillon earthquake (Stickney, 2006, The 26 July 2005 M_W 5.6 Dillon, Montana Earthquake: Seismological Research Letters, v. 77, p. 209) was completed in October 2008. August 2005 had over 360 earthquakes that had remained un-reviewed for over three years, 254 of which were Dillon aftershocks.

Over three years, this cooperative agreement supported 52 visits to MRSN seismograph and telemetery stites for repairs and maintenance. Significant improvements to the field seismograph stations and telemetry equipment included modifications to the Centennial telemetry link, which extends from Earthquake Lake (just west of Yellowstone National Park) back to Butte and includes stations QLMT, TPMT, MOMT, MCMT and HBMT. In September 2008 with assistance of Ken Whipp of the University of Utah Seismograph Stations, we rearranged VCO frequencies, changed one RF transmit frequency, and moved and modified RF receivers and antennas. This week-long effort eleminated radio self-interference and spurious telemetery noise and dramatically improved the relilability and data quality from these five seismic stations. In October 2007, again with help from Ken, we modified the telemetry repeater/seismic station on Mount Belmont (BEMT) northwest of Helena, Montana. We changed radio telemetery frequencies on one of the three links that repeat to this site and installed tuning cavities on all three receivers to eleminate RF interference from other radios operating at this much-used site. When Ken visited in September 2009, we rebuilt the Ninemile Divide telemetry repeater/seismograph site (NDMT). This work greatly improved the received RF signal strength from station BHMT and eliminated self interference between the transmitter and receivers at the site. These annual efforts to modify existing seismic stations and telemetry repeaters with Ken's help and expertise have resulted in dramatic reductions of telemetry interferrence and noise problems and equally dramatic improvements in station reliability and data quality.

With assistance from Earthworm support in Memphis, we are now running SeisNetWatch software on the Earthworm data acquisition system in the Earthquake Studies Office. We send automatic and reviewed eartrhquake hypocenter solutions and magnitudes for earthquakes of magnitude 1.0 and larger to the

USGS website (http://earthquake.usgs.gov/earthquakes/recenteqsus/) using QDDS. The MBMG Earthquake Studies Office website (http://mbmgquake.mtech.edu/) provides webicorder records, which are updated every five minutes, for all MRSN stations (plus other regional stations), a network station map and station locations.

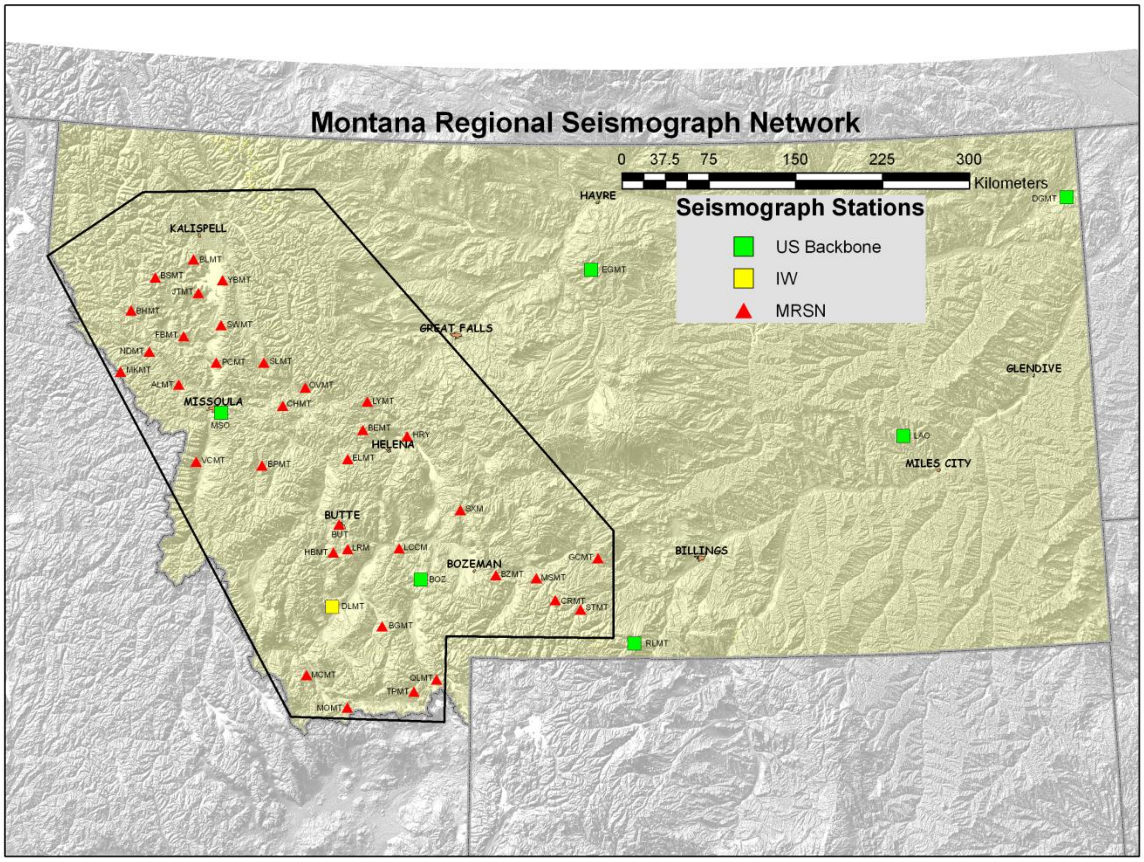

Figure 1. Red triangles are seismograph stations of the Montana Regional Seismograph Network (MRSN). All MRSN stations consist of an analog telemetered, short-period vertical seismometer except station BLMT (the northern-most station), which is a digital station that also includes a three-component accelerometer and station BUT, which includes a pair of analog, short-period, horizontal seismometers that have simulated Wood-Anderson seismograph response. Green squares are ANSS backbone stations in Montana and the yellow square is a USGS broadband station that is belongs to the Intermountain West network. The black polygon shows the MRSN authoritative boundary. MRSN station locations are available on the Earthquake Studies Office website: http://mbmgquake.mtech.edu/MRSNloc.html.

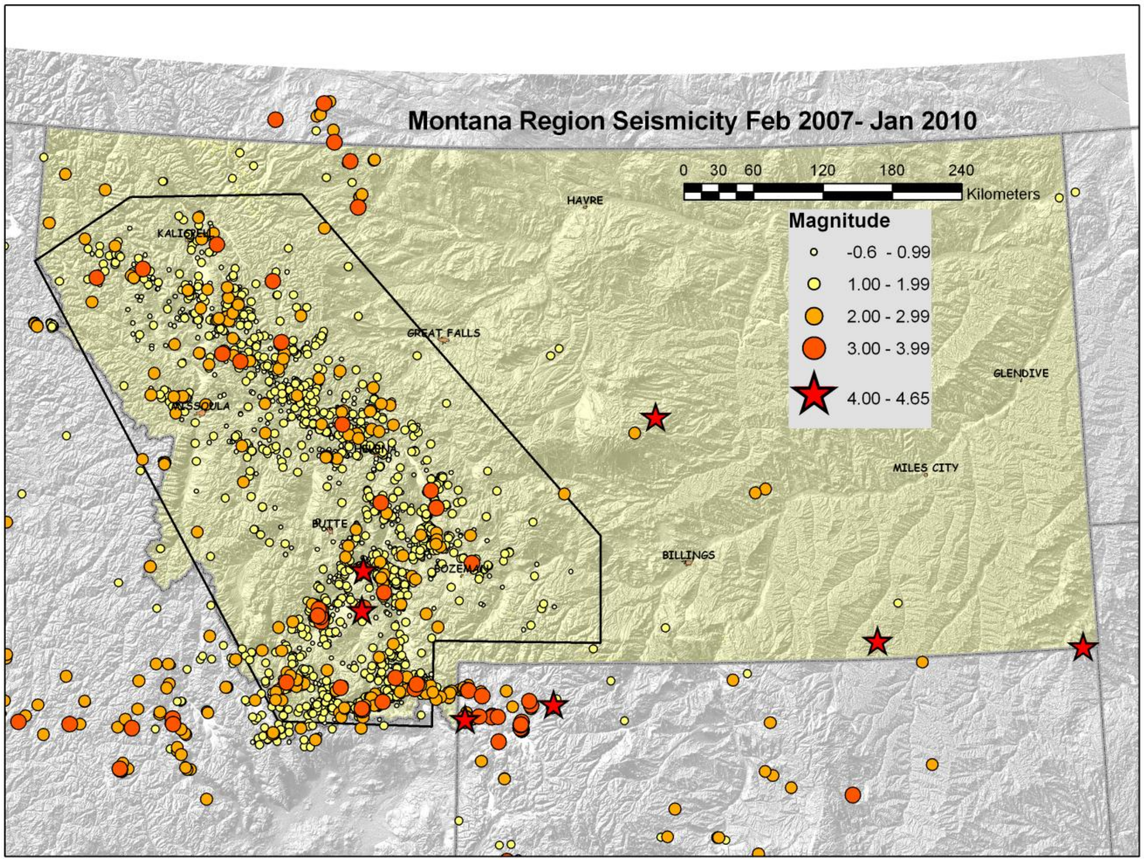

Figure 2. Epicenter locations for 4480 earthquakes located using data from the Montana Regional Seismograph Network for the period February 2007 through January 2010. Earthquakes in Yellowstone National Park were fixed at University of Utah Seismograph Seismograph Station hypocenter coordinates. The black polygon shows the MRSN authoritative boundary.

During the cooperative agreement period, we located a total of 4480 earthquake hypocenters (Figure 2) using MRSN data and reported these hypocenters to the ANSS composite catalog (http://quake.geo.berkeley.edu/cnss/). Magnitudes ranged from -0.6 to 4.7. Of the 4060 earthquakes that occurred with the MRSN authoritative atative region, 41 earthquakes had magnitudes greater than or equal to 3.0 and two had magnitudes greater than 4.0. The Earthquake Studies Office and the USGS *Did You Feel It?* website received felt reports for 16 earthquakes within the MRSN authoritative region and for another 23 earthquakes in the regions surrounding the MRSN authoritative region.

The largest earthquake within the MRSN authoritative region had a magnitude of 4.7 and occurred on May 8, 2007 near the town of Sheridan where it was felt with intensity V and caused minor damage to chimneys and a brick parapet. The Sheridan earthquake occurred in the Ruby Valley, a region of sparse historical seismicity. With a fault plane solution indicating normal slip on a northwest-trending fault and a hypocenter depth of 13.5 ± 0.4 km, this earthquake likely occurred at depth along the Ruby Range northern border fault (Stickney, 2008, The May 8, 2007 Sheridan, Montana Earthquake: Seismological Research Letters, v. 79, p. 294).

On March 6, 2009, a magnitude 4.2 earthquake shook the Jefferson Valley of southwest Montana with a maximum intensity of IV. Although the epicenter of this earthquake lies close to the Tobacco Root fault, the 11.7 ± 0.4 km depth precludes slip along this west-dipping range front fault. This area of the Jefferson Valley has been recurrently active with over 800 earthquakes within 10 km of this epicenter since 1982, including the October 28, 1989 magnitude 4.1 earthquake (Stickney, 2002, The October 28, 1998 Waterloo, Montana Earthquake: Northwest Geology v. 31, p. 87-88).

Another significant development was the routine use of EarthScope Transportable Array (TA) data for hypocenter locations. Between September 2006 and January 2010, TA stations operated at 84 sites in Montana. Of the 104,447 phase arrival times (mostly P picks but also some S picks) used to locate 4480 earthquakes during this cooperative agreement term, 27.8 per cent came from TA stations. With their gridded deployment pattern, the TA stations provided unprecedented seismographic coverage of large regions of Montana that have not previously had any decent regional monitoring coverage.

Three earthquakes with magnitudes ranging from 4.1 to 4.2 occurred in eastern Montana. A magnitude 4.2 earthquake occurred in central Montana on November 26, 2007 and was felt with a maximum intensity of III. An August 22, 2009 earthquake of magnitude 4.0 occurred in the Powder River Basin of southeastern Montana and was felt by a few local residents. On September 22, 2009 and earthquake of magnitude 4.2 occurred in extreme southeastern Montana near the town of Alzada where it was felt with intensity IV. All three of these earthquakes occurred in regions of very low historic seismicity that may in some measure be due to the very limited seismic monitoring coverage previously available in eastern Montana. The hypocenter locations all three of these earthquakes greatly benefited from data recorded by the TA.

Using funding from a state equipment grant, the MBMG is in the process of adopting 10 TA vaults in Montana as permanent seismograph stations. Each vault will be instrumented with a 3-component accelerometer and a short-period vertical seismometer with digital data continuously streamed to the Earthquake Studies Office via spread-spectrum radios and the internet.

Data Management Practices

The MRSN currently exchanges real-time waveform data via Earthworm import/export modules with the USGS National Earthquake Information Center, University of Utah Seismograph Stations, Idaho National Labs, BYU Idaho, University of Idaho, University of Washington and receives data from the Canadian Geological Survey. Also, the MRSN receives real-time Transportable Array waveform data from the IRIS DMC using the slink2ew Earthworm module.

Presently, automatic picks are sent to the USGS in Golden, CO as part of a testing phase for the national system. None of the surrounding seismic networks have requested phase picks or amplitude data from the MRSN but we are willing to provide these data if such requests are forthcoming.

The IRIS DMC extracts and archives data from our public Earthworm waveserver in near real-time where it is immediately available to external users. Automatic event locations are posted to our website (http://mbmgquake.mtech.edu/) within three minutes of their occurrence. Significant events are reviewed as quickly as possible (~30 minutes under the best circumstances) and posted to our website (http://mbmgquake.mtech.edu/earthworm/reviewed_locations.html). All local earthquakes are manually reviewed and posted to the website, typically within 24 hours but up to 72 hours during weekends and holidays. Whenever reviewed earthquake locations are posted to our website, we also contribute reviewed hypocenter solutions and magnitudes to the ANSS composite catalog (http://quake.geo.berkeley.edu/cnss/). Earthquake catalogs, phase picks and other data collected by the MRSN are also available by request from the Earthquake Studies Office at the email address provided on the title page.

Continuity of Operations and Response Planning

The Earthworm data acquisition system includes a group of four rack-mounted UPS systems to power six servers. Each server has a duel power supply powered by separate UPS systems. Three additional UPS systems power the system clocks, discriminator racks, digitizer, and radio telemetry receivers. Thus locally recorded seismic signals will continue to be recorded in the aftermath of a power outage. The Earthquake Studies Office, along with the rest of the MBMG, has just moved into the new Natural Resources Building on the Montana Tech campus. The new Earthquake Studies Office is connected to a diesel generator backup power system that automatically starts up within a few seconds of an interruption of utility power. When all of the data acquisition equipment is moved into the new building, the UPS system should only have to carry the acquisition system for a few seconds before backup power is available. The two remote Earthworm nodes in Missoula and Ronan have UPS systems and wavetanks that store continuous data for about one month. So following a power outage that disrupts communications between the remote nodes and the Earthquake Studies Office, continuous waveforms from the remote nodes are fully recoverable.

A hardened campus computer/network system is gradually being implemented on the Montana Tech campus but at this time the ESO is dependant upon the campus IT department for real-time communications with the outside world.

As a newly designated Tier 2 network, the MRSN is partnering with the University of Utah Seismograph Stations to cooperatively use the ANSS Quake Monitoring System (AQMS) that has been installed and is currently being tested in Salt Lake City. Use of the AQMS will require that all MRSM data be copied to and stored at the University of Utah Seismograph Stations. Greater connectivity and sharing of an analysis system should provide a measure of redundancy and cooperation between the Utah and Montana regional networks. We are currently investigating redundant communication links between Montana and Utah.

Progress on Metadata Development

As a small regional network with limited staff, we rely on the IRIS DMC to provide metadata in standard formats to outside users (http://www.iris.washington.edu/bud_stuff/bud/bud_start.pl?BUDDIR=/budnas/virtualnets/ALL; select MB network). We have generated response information for our network stations so IRIS DMC can archive the MRSN waveforms.